Mousa *International Journal of Industrial Chemistry* 2013, **4**:26
http://www.industchem.com/content/4/1/26

International Journal of Industrial Chemistry (IJIC)
a SpringerOpen Journal

RESEARCH Open Access

The effect of feldspar and kaolin on mechanical performance of SBR/LDPE composites

Ahmad Mousa

Abstract

Background: Feldspar and kaolin was ball milled at 320 rpm for hours with the aid of a dry grinding agent. Both minerals were combined with inorganic salt namely sodium chloride as a grinding agent. The grinding agent and mineral were mixed at the ratio of 1:1.

Results: The application of such grinding agent led to effectively reduce the particle size in a short time. The mineral materials were viewed under a scanning electron microscope (SEM) before and after grinding. SEM graphs revealed that a significant reduction in average particle size was recorded for both minerals. The reduction percentage for kaolin was about 82%, and in the case of feldspar, it was about 93%. The BET surface area of both minerals increased after milling. The potential of the ground filler on the tensile properties of low-density polyethylene/styrene butadiene rubber (LDPE/SBR) composites has been reported.

Conclusions: The ball milling of the raw fillers in the presence of inorganic salt was found to be able to reduce the particle size of the fillers significantly in a short time. The application of dry grinding agent did not display any agglomeration or cold welding between the mineral particles as evidenced by the SEM images. The incorporation of the ground filler into LDPE/SBR composites showed a positive impact on the tensile strength at the cost of elongation at break except for the feldspar.

Keywords: Ball milling, Feldspar, Kaolin, Dry grinding

Background

Comminution is the process whereby particular materials are reduced from coarse feed to fine product size for end use [1]. Comminution can be performed either by wet or dry means [2]. Such operation is utilized in various industrial processes such as ceramics, agricultural products, food, pigments, and composite materials. To recall, ultrafine grinding is an energy-intensive process as far as fine-sized particle achievement is concerned. Nevertheless, grinding has been applied over the years due to the fact that various mineral fillers can be made into useful products or ingredients when crushed to a smaller size range [3-6]. It is important to note that such powders are cheap materials that can be incorporated into polymers to improve the technical utility of the mineral powder. The potential of such minerals will be great as long as their particle size is small enough, since fine powders will have higher surface area to utilize in producing polymer composites. Such composites are expected to display enhanced mechanical properties and thermal performance. Furthermore, the barrier properties are expected to increase with the use of the proper mineral filler powder. The effect of inorganic electrolytes such as sodium hydroxide and soap on grinding of minerals has been investigated by several workers [7,8]. The current investigation has dual purpose; firstly, it aims to produce fine particle-sized minerals with increased specific surface area in the presence of sodium chloride as grinding agent via ball milling. Secondly, it aims to examine the potential of the powders as a reinforcing agent for low-density polyethylene/styrene butadiene rubber (LDPE/SBR) composites compared to raw powders.

Methods

Materials

LDPE, with a grade of L705 with MFI 0.20 g/min and a density of 0.918 g/ml, was obtained from Polyolefin Company (Singapore, Singapore). Styrene butadiene

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rubber (Buna Hüls 1502) produced by Bayer (M) Ltd, (Petaling Jaya, Malaysia) is obtained from a local rubber processing factory. Commercial grade coarse sodium chloride was purchased from a local market (Jordan). Kaolin and feldspar minerals in raw form were obtained from a mine at the Kingdom of Saudi Arabia, and the initial particle size was 173 and 495 μm, respectively.

Filler treatments

The mineral filler was tumbled ahead with a dry grinding agent to load into a ball mill. The tumbled powder was loaded into the ball mill. The powder was ground at a speed of 320 rpm for 4 h. The powder was removed from the mill and soaked in water to dissolve the salt used as grinding agent. The suspension that contains powder was filtered and washed with water several times. The washed powder was dried in a hot air oven for 24 h at 100°C. The specific surface area of the powder was measured using the Brunauer, Emmet, and Teller (BET) method [9]. The average particle size of the raw and milled powder was determined using the software of the XL-30 scanning electron microscope (SEM).

Results and discussion

The effect of ball milling on filler particle size and surface area

The effect of ball milling for hours at 320 rpm in the presence of the inorganic grinding agent on the particle size of kaolin and feldspar is presented in Figure 1; it is compared with the untreated counterpart. It is clear that the average particle size for both minerals was reduced after milling from 495 to 35 μm for feldspar, whereas the size was down from 195 to 38 μm for kaolin. In terms of percentage reduction, it was about 93% for feldspar mineral and about 82% in the case of kaolin mineral. The observed trend should be due to the influence of the milling process in the presence of inorganic salt. The grinding agent is expected to increase the friction between the balls and the grinding media since the grinding agent is harder than the mineral to be milled. As a result, the stress conferred to the mineral is expected to increase, causing the bulky size to rupture to a smaller size as shown in Figure 1. The reduction in the particle size obtained in Figure 1 is confirmed by the SEM graphs depicted in Figures 2 and 3. It is obvious that the particle size for kaolin and feldspar was minimized after milling, which is in conformity with the data shown in Figure 1. Note that the micrographs do not display any agglomeration of the minerals after the milling process. Hence, this is a clue that the addition of the dry grinding agent did not cause any cold welding between the particles of the minerals. The implication is that the grinding agent has dual functions: the former is as grinding aid, and the latter is as matrix separation agent that prohibits the formation of agglomerates. To further support the enhancement of

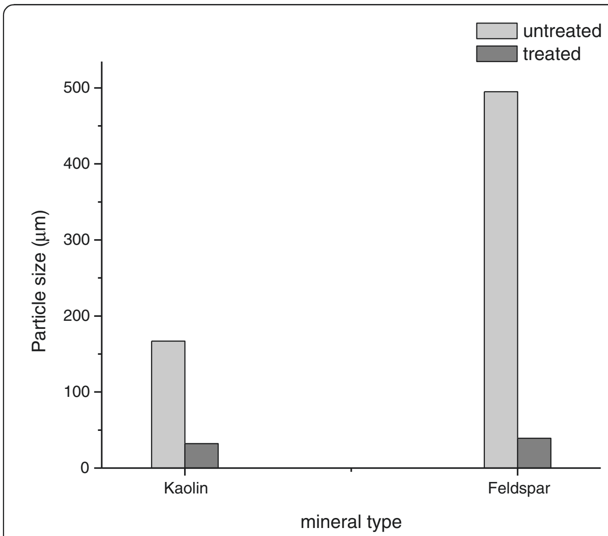

Figure 1 Effect of ball milling on the average particle size of kaolin and feldspar. Kaolin and feldspar are milled for 4 h at 320 rpm.

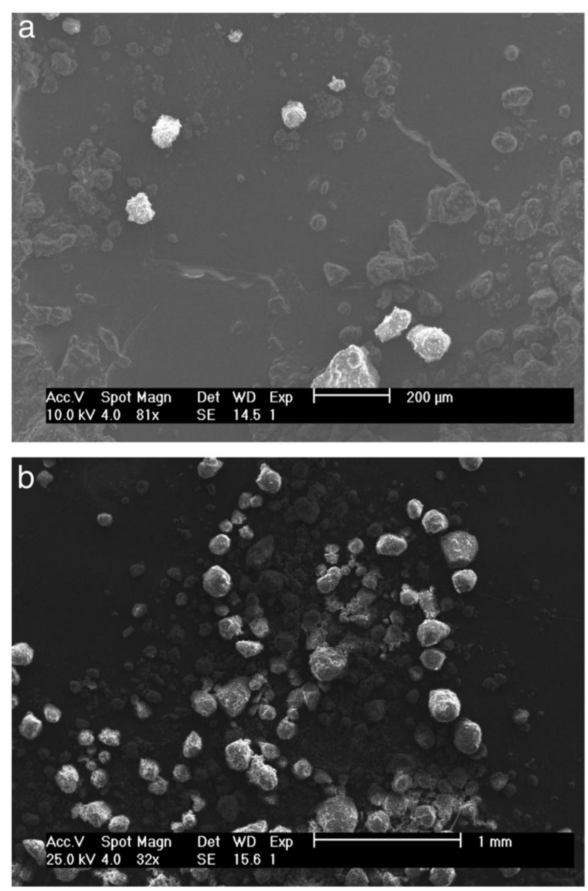

Figure 2 SEM images of kaolin. (**a**) Before and (**b**) after ball milling for 4 h and 320 rpm.

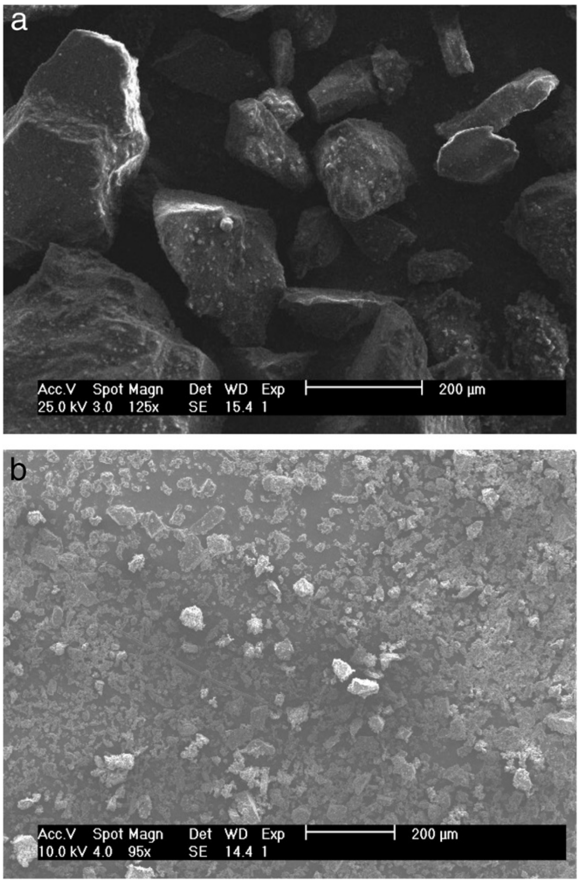

Figure 3 SEM images of feldspar. (**a**) Before and (**b**) after ball milling for 4 h and 320 rpm.

surface area, the BET surface of both feldspar and kaolin was checked as reflected in Figure 4. Obviously, due to the milling process, the surface area is increased as shown in Figure 4. This should be related to the creation of new surfaces after milling. The new surface will have larger surface areas.

The effect of fine fillers on the mixing torque of LDPE/SBR composite

Figure 5 shows the effect of the untreated and treated mineral fillers on the equilibrium torque (torque at the end of the mixing process) of the LDPE/SBR composites obtained from the Brabender plasticorder. It is clear that the mixing torque of the composite filled with treated fillers is higher than the composite with untreated fillers. This is likewise to be attributed to the enhanced degree of interaction between the treated fillers and the matrix. Since it is well known that the smaller the particle size, the larger the surface area, hence, a better degree of interaction with improved dispersion state was achieved. As a result, the mixing torque increased as

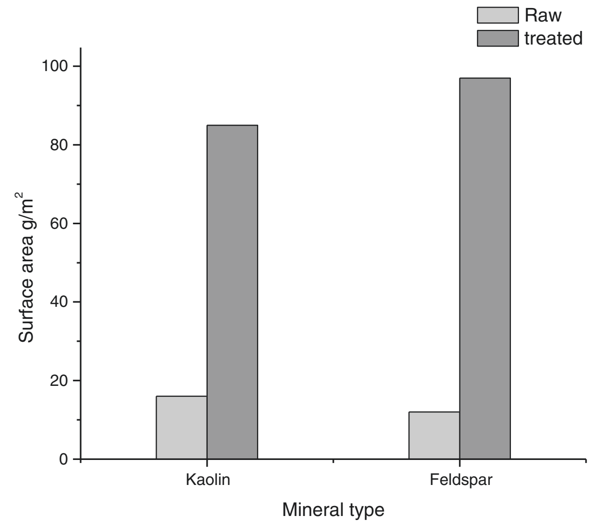

Figure 4 BET surface area of kaolin and feldspar. Before and after ball milling 4 h and 320 rpm.

demonstrated in Figure 5. This is in line with previous works on filled similar polymer composites [10,11]. It is worth mentioning that the equilibrium torque displayed by the composite-based feldspar is less than that of the kaolin-based feldspar, although the surface area of feldspar is larger. This is most likely due to the platy shape of the feldspar which acts as internal lubricant for the composite. The last conclusion from Figure 5 is that the equilibrium torque of the plain composite is the least among the whole composites. Similar findings were reported earlier in the case of the platy shape

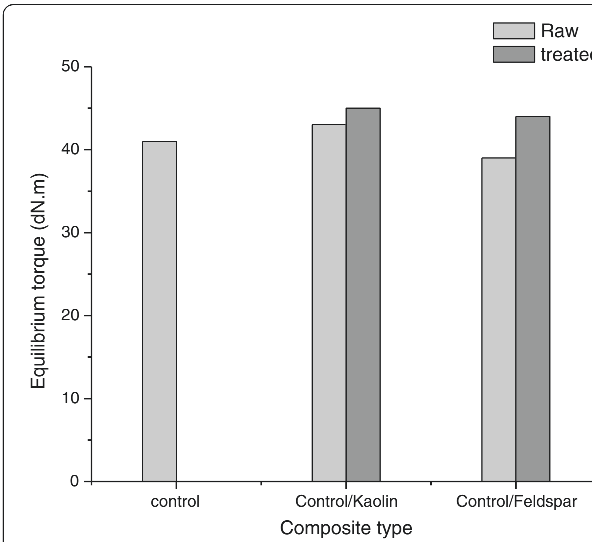

Figure 5 Influence of untreated and treated mineral filler on the equilibrium mixing torque of SBR/LDPE composites.

including nanoclay mineral fillers on the torque and viscosity of polymer composites [12,13].

Tensile properties

Figure 6 reflects the influence of the untreated and treated filler on the tensile strength at the breaking of the prepared samples. Note that the incorporation of the treated fillers increased the tensile strength at the breaking as compared with the pristine filler. This is due to the improved interaction between the treated fillers and the matrix, which in turn, increased the work of adhesion of the composites against the external stress. Furthermore, the treated filler is expected to contribute to the stress transfer mechanism, which means that the filler will sustain some of the external load that leads to the observed trend. Considering the influence of the treated filler on the modulus of elasticity of the prepared composites shown in Figure 7, it is clear that the modulus increased after the incorporation of the treated filler. This indicates quite well that the stiffness and rigidity of the composites increased after the addition of mineral fillers. This could be due to the fact that the mineral filler is a highly rigid material. Thus, the rigidity will be conferred to the matrix. In addition to this, the improved degree of interaction mentioned earlier is also responsible for the increased value of the modulus. Again, the rigidity of the feldspar-based composites is lower than that of the kaolin-based composite; this is due to the lubrication action practiced by the platelike feldspar discussed earlier, which is in line with the equilibrium torque results. Figure 8 shows the course of the percentage elongation at the breaking (%EB) of the LDPE/SBR composites after the incorporation of the treated fillers. It is clear that the %EB decreased after the incorporation of kaolin. This should be due to the occupation of the free volume of the matrix by the kaolin mineral, which increased the rigidity and decreased the compliance of the composites. Therefore, the extensibility of the matrix decreased prior to failure. On the other side, the addition of feldspar increased the %EB as compared with the kaolin-based composite. Such discrepancy might be due to the platy structure of the feldspar, which, in turn, might act as the internal lubricant that allows the matrix to be elongated, to a better extent, to rupture [11,14]. It is worth to recall that both fillers displayed lower strain as compared with the control sample. The observed trend is in line with the earlier report on the

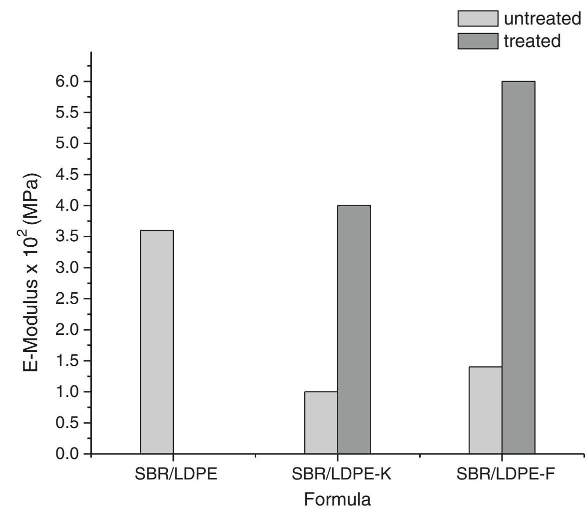

Figure 7 Influence of untreated and treated mineral filler on tensile modulus of SBR/LDPE composites.

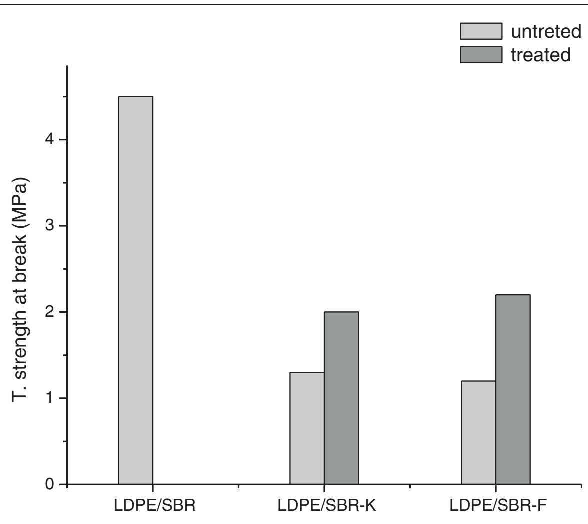

Figure 6 Influence of untreated and treated mineral filler on tensile strength at the break of SBR/LDPE composites.

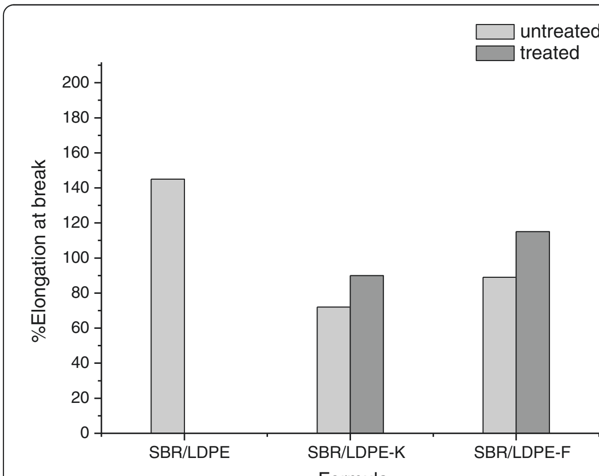

Figure 8 Influence of untreated and treated mineral filler on percentage elongation at the break of SBR/LDPE composites.

effect of feldspar on the performance of recycled PET/SBR composites [11,12].

Conclusions

Based on the aforementioned results, the following conclusions can be drawn:

1. The ball milling of the raw fillers in the presence of inorganic salt was found to be able to reduce the particle size of the fillers significantly in a short time. This was due to the increased stress on the minerals in the presence of the dry grinding agent. Simultaneously, the BET surface area of the minerals increased as such.
2. The application of the dry grinding agent did not display any agglomeration or cold welding between the mineral particles as evidenced by the SEM images.
3. The incorporation of the ground filler into LDPE/SBR composites showed a positive impact on the tensile strength at the cost of elongation at the break except for the feldspar. This was due to the enhanced interaction between the matrix and the fillers.

Competing interests
The author declares that he has no competing interests.

Acknowledgments
The author acknowledges, for his final year project, Feras al Tayeb for his help in running some experiments.

Received: 11 November 2012 Accepted: 5 February 2013
Published: 18 March 2013

References
1. Russell A (1989) Fine grinding - a review. Industrial Minerals 259:59–70
2. Gupty CK (2003) Extraction flowsheets. In: Chemical metallurgy: principles and plastics. Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim
3. Lynch A, Rowland C (2005) Hand stones. In: The history of grinding. Society for Mining, Metallurgy and Exploration, Littleton, CO
4. Florez-Zamora MI (2008) Comparative study of Al-Ni-Mo alloys obtained by mechanical alloying in different ball mills. Rev Adv Mater Sci 18:301
5. Kwade A, Bernotat B (2002) Present and future treads in dry fine grinding. Industrial Minerals 412:69–71
6. Jankovic A, Dundar H, Mehta R (2010) Relationships between comminution energy and product size for a magnetite ore. J South Afr Inst Min Metall 110:141–146
7. Brown JH (1955) M.I.T. progress report. NYO 7172:97
8. Stanzyk MH, Feld IL (1981) Comminution by the attrition grinding process 1981. US Bureau of Mines, Washington DC
9. Digabel L, Boquillon F, Dole N, Monties P, Averous BL (2004) Properties of thermoplastic composites based on wheat-straw lignocellulosic fillers. J Appl Polym Sci 93:428–436
10. Mousa A, Heinrich G, Wagenknecht U (2008) The potential of O-MMT as a reinforcing filler for uncured and dynamically cured PVC/XNBR composites. J Macromolecular Science, Part A Pure and Applied Chemistry 45:733–741
11. Mousa A (2008) On the potential of feldspar sand for recycled PET/SMRL composites. J of Elastomers and Plastics 40:179–190
12. Mousa A, Karger-Kocsis J (2001) Rheological and thermodynamic behavior of SBR/organoclay nanocomposites. Macromolecules Materials Engineering 286:260–266
13. Mousa A, Banerjee S (2009) The effect of nano layered silicate on mechanical properties of polypropylene composites. University of Sharjah Journal of Pure & Applied Sciences 6:21–34
14. Teh PL, Mohd Ishak ZA, Hashim AS, Karger-Kocsis J, Ishiaku US (2004) On the potential of organoclay with respect to conventional fillers (carbon black, silica) for epoxidized natural rubber compatibilized natural rubber vulcanizates. J Appl Polym Sci 94:2438–2445

doi:10.1186/2228-5547-4-26
Cite this article as: Mousa: The effect of feldspar and kaolin on mechanical performance of SBR/LDPE composites. *International Journal of Industrial Chemistry* 2013 **4**:26.